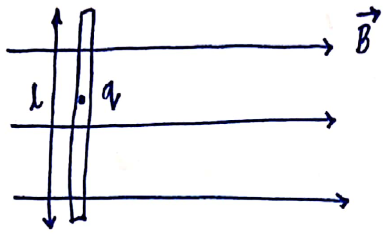
ELECTROMAGNETIC INDUCTION AND ELECTROMAGNETIC WAVE

Q1. Find the emf induced in a conducting rod moving through a uniform magnetic field.

∴



Let us consider, a charge 'q' inside the conductor.

Hence;

∴ $$\text{Force due to magnetic field} = q(\vec{v}\times\vec{B})$$

But due to moving of charge, an electric field is also produced.

Hence,

$$\text{Force due to electric field} = qE$$

∴ But 'q' is stationary;

$$\cancel{q}E = \cancel{q}(\vec{v}\times\vec{B})$$

and $$V = \underline{E}\times L$$

∴ $$E = \frac{V}{L}$$

Hence; $$\frac{V}{L} = (\vec{v}\times\vec{B})$$

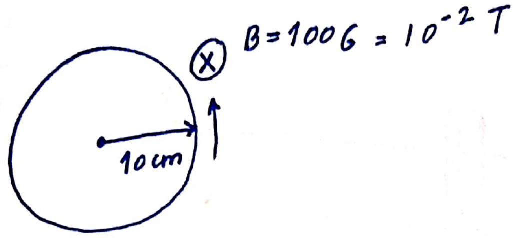
$$\Rightarrow V = L(\vec{v}\times\vec{B})$$

∴ $$\boxed{\mathcal{E} = Bvl\sin\theta}$$

Q. A vertical copper disc of diameter 20cm, makes 10 revolution per second about a horizontal axis. A uniform magnetic 100G acts ⊥r to the plane of disc.

Calculate the potential difference between it's centre and rim in volts.

∴



∴ $\omega = 2\pi f = 2\pi(10) = 20\pi$ rad/s

$\omega = 62.83$ rad/s

∴ $E = \frac{1}{2} B \omega l^2$

$= \frac{1}{2} \times 10^{-2} \times 62.83 \times (0.10)^2$

$\varepsilon = 3.14 \times 10^{-3}$

Q. How many volts are generated in a wire 10cm long which cuts directly across a magnetic field of flux density 1.4 Wb/m² it is moved at a speed of 2 m/s.

∴ $B = 1.4$ Wb/m²

$l = 10 \times 10^{-2}$ m

$v = 2$ m/s

∴ $E = Bvl$

$= 1.4 \times 0.1 \times 2$

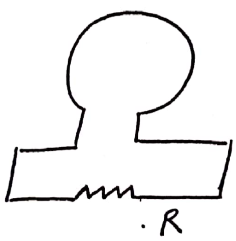
$E = 0.28$ V Ans.

Q. In figure, the magnetic flux through the loop is ⊥r to the plane of the coil and directed into the paper.

$\phi = 3t^2 + 4t + 1$, where

ϕ is in mW. What is the magnitude of emf induced at t = 2s.

What is the direction through R

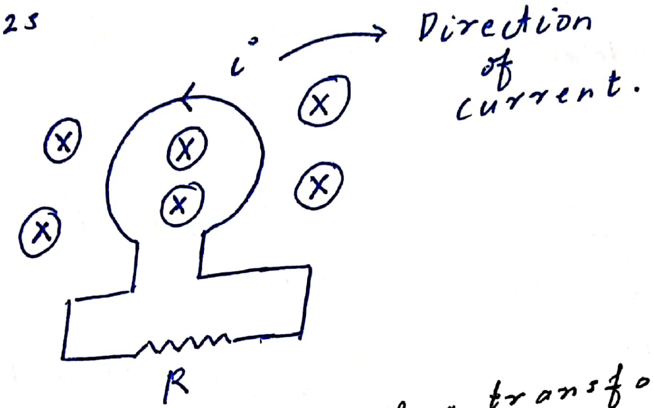


$$\therefore \quad E = \left|\frac{d\phi}{dt}\right|$$

$$E\Big|_{t=2s} = 6t + 4$$

$$E\Big|_{t=2s} = 16 \text{ mV}$$

$\therefore$



Q. A current in a primary coil of a transformer changed from 0.5 A to 0 in 1 ms. The emf induced in the secondary coil is 500V. Calculate the mutual inductance between the coil.

$$\frac{di}{dt} = \frac{\Delta i}{\Delta t} = \frac{I_f - I_i}{\Delta t}$$

$$\therefore \quad E = -M\frac{di}{dt}$$

$$\therefore \quad E = -M\left[\frac{0 - 0.5}{10^{-3}}\right]$$

$$\therefore \quad 5\cancel{0}0 = M\left[0.5 \times \cancel{10}^{3}\right]$$

$$M = 1 \text{ Henry}. \quad \text{Ans.}$$

Q. A varying magnetic flux passing through $\perp^r$ly through coil is given as

$$\phi_B = 20\sin(5\pi t) + 5t^2 + 50 \text{ mW}$$

What is the emf induced in the coil at $t = 2$ seconds.

$$\therefore \quad E = \left|\frac{d\phi_B}{dt}\right| = \left|20\cos(5\pi t)(5\pi) + 10t\right|$$

$$E\Big|_{t=2} = \left|20\cos[\cancel{10\pi}]^{1} + 20\right| = 40$$

Q. The electric field associated with an electromagnetic wave propogating through a lossless medium of relative permitivity and relative permeability $\mu_r = 1$, expressed as ↳ $\epsilon_r = 7.5$

$$\vec{E}_y = 25\cos(8\pi \times 10^3 t - \beta x)\hat{i}$$

Calculate
1. Phase constant
2. Wavelength
3. Intrinsic independence

Phase Velocity:

$$\therefore V_{phase} = \frac{c}{\sqrt{\epsilon_r \mu_r}} = \frac{3\times10^8}{\sqrt{7.5\times1}} = 1.095\times10^8 \, m/s$$

(i) Phase constant

$$\therefore \beta = \frac{\omega}{V_p} = \frac{8\pi\times10^3}{1.095\times10^8} = 7.2\times10^{-4} \, rad/m$$

(ii) wavelength

$$\therefore \lambda = \frac{2\pi}{\beta} = \frac{2\pi}{7.2\times10^{-4}} = 8.72\times10^3 \, m$$

$\therefore$ (iii) Intrinsic Independence (η)

$$\therefore \eta = \eta_0 \sqrt{\frac{\mu_r}{\epsilon_r}}$$

$\eta_0 = 377\,\Omega$ for free space

$$\eta = 377\sqrt{\frac{1}{7.5}}$$

$$\eta = 137.7\,\Omega$$ Ans.

Q. A 6 GHz uniform plane wave is propogating in a lossless material medium of relative $\epsilon_r = 4$ if the amplitude of the electric field intensity is 600V/m. Find

1. velocity of propogation
2. wavelength
3. Phase constant
4. Intrinsic Independence
5. Propogation constant
6. Amplitude of magnetic field intensity.

∴ (i) velocity of propogation

$$V_p = \frac{c}{\sqrt{\epsilon_r \mu_r}} = \frac{3\times10^8}{\sqrt{4\times1}} = 1.5\times10^8 \text{ m/s}$$

(ii) Wavelength

$$\lambda = \frac{V_p}{f} = \frac{1.5\times10^8}{6\times10^9} = 0.025 \text{m}$$

(iii) Phase constant

$$\beta = \frac{2\pi}{\lambda} = \frac{2\pi}{0.025} = 251.3 \text{ rad/m}$$

(iv) Intrinsic Independence (η)

$$\eta = \eta_0 \sqrt{\frac{\mu_r}{\epsilon_r}} = \frac{377}{2} = 188.5\ \Omega$$

(v) Propogation Constant (γ)

$$\gamma = \alpha + i\beta$$
$$\gamma = 0 + i(251.3)$$
$$\gamma = i\,251.3$$

$\alpha \rightarrow$ Attenuation constant
$\alpha = 0$ for lossless medium.
$\beta \rightarrow$ phase constant
$i \rightarrow$ iota

Magnetic Field intensity;

(vi) $$H_0 = \frac{E_0}{\eta} = \frac{660}{188.5} = 3.18 \text{ A/m}$$

Q. In a plane electromagnetic wave, the electric field oscillate sinusoidally with a frequency of 2×10^{10} Hz and amplitude 48 V/m.

(a) What is the wavelength of the wave?

(b) What is the amplitude of the oscillating magnetic field?

(c) What is the total average energy density of the electromagnetic field of the wave.

(d) Electromagnetic wave travel in a medium at a speed of 2×10^{8} m/s. The relative permeability μ_R of the medium is 1. Find the relative permeability.

∴ (i) $\lambda = \frac{V_p}{f} = \frac{2\times10^8}{2\times10^{10}} = 10^{-2} = 1\,cm$

(ii) B_0

∴ $B_0 = \frac{E_0}{V_p}$

$\Rightarrow B_0 = \frac{48}{2\times10^8} = 24\times10^{-8}\,T = 0.24\,\mu T$

(iii) $U_E = \varepsilon_0 E^2 = 8.85\times10^{-12}\times(48)^2$ (For free space)

$U_E = 2.04\times10^{-8}\,J/m^3$

(iv) $V_p = \frac{c}{\sqrt{\varepsilon_r \cdot \mu_r}}$

$2\times10^8 = \frac{3\times10^8}{\sqrt{\varepsilon_r\times1}}$

∴ $\varepsilon_r = (1.5)^2$

$\varepsilon_r = 2.25$ Ans.

Q. The electric field of a plane electromagnetic wave in vacuum is represented by;

$E_y = 0.5\cos\left(2\pi\times10^8\left(t - \frac{x}{c}\right)\right)$

$E_x = 0$

with $c = 3\times10^8$ m/s. and all quantities in SI unit and E_z is also 0.

(i) What is the direction of the wave?

(ii) What is wavelength

(iii) Compute the components of Magnetic field associated with a wave.

B. ~~z 0 [illegible]~~

Sol. (i) Wave propogates in +x direction

(ii) $\lambda = \frac{2\pi}{\beta} = \frac{2\pi\times3}{2\pi} = 3\,m$

(iii) $B_0 = \frac{E_0}{c}$

∴ $B_z = \frac{0.5\times10^{-8}}{3} = 1.67\times10^{-9}\,T$

$B_x = 0$, $B_y = 0$

B_x and B_y isliye 0 hai kyunki every component is ⊥r to each other

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These handwritten notes are of PHY-S102 taught to us by Prof. Prabal Pratap Singh, compiled and organized chapter-wise to help our juniors. We hope they make your prep a bit easier.

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